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EUROPEAN PATENT APPLICATION

21 Application number: 88304471.1

51 Int. Cl.⁴: F 28 D 9/02
 F 28 D 1/03, F 28 F 3/08

22 Date of filing: 17.05.88

30 Priority: 21.05.87 AU 2056/87

43 Date of publication of application:
 23.11.88 Bulletin 88/47

84 Designated Contracting States: DE FR GB IT SE

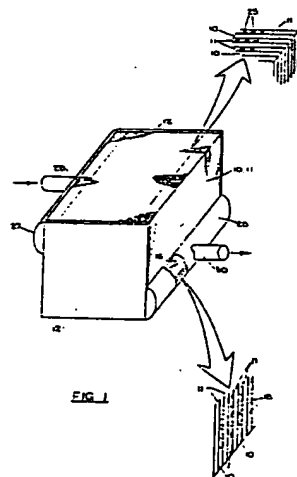
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54 Flat-plate heat exchanger.

57 A flat-plate heat exchanger having first and second groups of the plates (10 and 11), the plates of one group being interleaved with those of the other group. Each of the plates (10 and 11) is formed within one face with a fluid flow passage (13 and 20), the passage (13, 20) being constituted by a plurality of channels (18 and 25) which are formed within the thickness of the plate (10, 11). The fluid flow passages (13) within the first group of plates (10) extend between side edges (15 and 17) of the plates (10, 11) and, in so doing, the passages (13, 20) make an odd number of transverse passes across the width of the plate (10, 11), and headers (27 and 28) are located at the respective side edges of the heat exchanger for directing a first heat exchange fluid into and from the fluid flow passages (13) in the first group of plates (10). The fluid flow passages (20) in the second group of plates (11) extend from one end (22) of the plates (11) to the other end (24), in a linear direction.



Description

FLAT-PLATE HEAT EXCHANGER

This invention relates to a heat exchanger of a type having flat plates which are formed within their thickness with fluid passages and which are bonded together as laminations without any intervening gaskets.

Such heat exchangers have been developed to provide for counterflow, crossflow or coflow of heat exchange fluids but, in all cases, the fluid passages in individual plates have been formed to provide for flow which is generally unidirectional. The flow paths in some cases have incorporated turbulence inducing geometries such as zig-zag channels or flow diverters. Also, some plates have been formed with distribution zone channels and smoothing zone channels which may extend transversely or obliquely to the general direction of passages in the heat exchange region of the plates. However, even with these various passage arrangements, the individual plates have been designed and arranged to provide for flow in one direction only in the heat exchange region of the plates and the passages within such region do not provide for reverse direction flow of fluid within the length or width of the plates.

In contrast with the known types of heat exchangers, the present invention provides a structure having plates which are formed with fluid flow passages which make an odd number of passes across the width or along the length of the plates and which, in so doing, provide for reversal of fluid flow within the boundaries of each of the plates.

Thus, the present invention may be broadly defined as providing a heat exchanger which comprises a plurality of flat metal plates which are bonded together as laminations in face-to-face contact without any intervening gaskets. A first group of the plates has a first fluid flow passage formed in one face of each plate of the group, and a second group of the plates has a second fluid flow passage formed in one face of each plate of the group. Means are associated with the first group of plates for directing a first fluid into and from the fluid flow passages in that group of plates and for keeping the first fluid separate from a second fluid which is in use directed through the fluid flow passages in the second group of plates. The first and second fluid flow passages in the respective plates each comprise a plurality of channels which are formed within the thickness of the respective plates. The channels in at least the first group of plates make an odd number of passes across the width or along the length of the plates and the channels within each fluid flow passage have approximately the same length.

The above defined structure provides certain distinct advantages over prior art heat exchangers of the same general type. Thus, in contrast with prior art counterflow exchangers, the present invention enables a single plate size to be used to produce a very wide range of heat exchange characteristics, without substantial variation in passage size. Also, the present invention avoids the need for a distribu-

tion zone and thus obviates the pressure drop and inefficient heat transfer which is normally associated with a distribution zone. Consequently, counterflow exchange may be no more costly to produce than crossflow exchange.

When compared with prior art crossflow exchangers, the present invention permits a single plate size and shape to be used to handle fluids with widely different flow rates and/or viscosities, without there being a need for extreme length-to-width ratios. Also, counterflow can be approached to any desired approximation by pursuing the fluid back and forth across the width or along the length of the plates and by appropriately patterning adjacent plates, without complex baffling being required in fluid headers. Additionally, small diameter fluid headers may be employed for fluids which are directed through those plates which provide for reversal of flow, and the heat load from side-to-side of the plate may be more even in the heat exchanger as contemplated by the present invention.

Each plate may be formed in each of its faces with fluid passages or, in the alternative, each plate may be formed in one face only with the fluid passages. Also, a complete heat exchanger may be constructed with all of its plates being of one type or the other, or with a mixture of the two types of plates. When the plates are formed in both faces with the fluid passages, adjacent plates may be bonded together to create double-depth passages, or adjacent plates may be separated by spacer plates which serve to separate the fluid streams.

However, it is expected that most heat exchangers will be constructed with plates which are formed in one face only with fluid passages and, in such case, two groups of interleaved plates will be provided within the heat exchanger, one group being used to convey one fluid and the second group being used to convey the other fluid.

The passages in both groups of plates may provide for reversal of fluid flow, although the heat exchanger may be constructed such that the passages in one group of plates provide for reversal of fluid flow while the passages in the other group of plates provide for straight-through fluid flow. When both groups of plates are formed with passages which provide for reversal of fluid flow, one group of plates may be provided with passages which extend predominantly in a longitudinal direction and the other group of plates with passages which extend predominantly in a transverse direction. Alternatively, both groups of plates may be provided with passages which extend predominantly in the same direction.

All of the channels which serve to form one fluid flow passage preferably have the same dimension, and each channel preferably has a cross-sectional dimension and shape which is substantially constant along the full length of the channel.

Each channel preferably has a depth in the range 0.2 to 1.5mm and a width not greater than approxi-

mately 5mm. It is most preferred that each channel has a width less than 3mm.

One heat exchange fluid would normally be directed into and from the heat exchanger by headers connecting with the inlet and outlet ends of the passages in one group of the plates. The other heat exchange fluid may be caused to pass through the heat exchanger by simply placing the exchanger in a fluid stream or bath. However, it will normally be the case that a first pair of headers will be employed for directing a first fluid into and from a first group of plates in the heat exchanger, while a second pair of headers will be provided for directing a second fluid into and from a second group of plates in the exchanger.

The fluid flow channels may be linear, but for direction reversing bends in the channels, or the channels may be shaped in any desired manner, for example, to follow a serpentine or zig-zag path.

The invention will be more fully understood from the following description of a number of different types of heat exchangers which incorporate the features of the invention. The description is provided with reference to the accompanying drawings and is not intended to be limiting on the scope of the invention.

In the drawings:

Figure 1 shows a perspective view of a first heat exchanger which is suitable for location in a fluid bath or stream,

Figure 2 shows an elevation view of a first plate which is incorporated in the heat exchanger of Figure 1 and, also, in the heat exchanger of Figure 4,

Figure 3 shows an elevation view of a second plate which is incorporated in the heat exchanger of Figure 1,

Figure 4 shows a perspective view of a second heat exchanger, which is suitable for thermally contacting two separately piped fluids,

Figures 5 and 5A show elevation views of alternative plates which may be incorporated in the heat exchanger of Figure 4, together with the plate as shown in Figure 2,

Figure 6 shows a perspective view of a heat exchanger which is suitable for contacting two fluids, one of which is directed into the heat exchanger by two separate pipes and conveyed from the heat exchanger by way of a single pipe,

Figure 7 shows a perspective view of a heat exchanger which provides for the supply and discharge of fluid from one side only of the heat exchanger, and

Figure 8 shows an elevation view of a plate which is incorporated in the heat exchanger of Figures 6 and 7.

As illustrated in Figure 1, the heat exchanger is constructed from a plurality of flat stainless steel plates 10 and 11 which are interleaved, laminated and bonded together in face-to-face relationship. The plates 10 and 11 are sandwiched between metal end plates 12 and all of the plates are diffusion bonded together at their contacting surfaces. To effect such bonding, the plates are pressed together

whilst subjected to a temperature approaching the melting point of the metal, whereby interfacial crystal growth is promoted. Compression is applied to the stack of plates during the bonding process in order to assure a sound bond and to compensate for any lack of plate flatness.

The plate 10, as shown in Figure 2, is formed with a fluid passage 13 which extends from an inlet region 14 in one edge 15 of the plate to an outlet region 16 in the opposite edge 17 of the plate. The fluid passage is constituted by a plurality of channels 18, each of which extends transversely across the plate in a first direction, downwardly in a longitudinal direction of the plate, transversely across the plate in a reverse direction, downwardly again in the longitudinal direction and then transversely of the plate in the first direction. Thus, the fluid passage as constituted by the channels 18 makes three passes across the width of the plate, although, in an alternative embodiment, the passage may make five or any other odd number of multiple passes as may be required. All of the channels 18 within the passage have approximately the same length and this is achieved only if the passage makes an odd number of passes.

The channels 18 are formed within the thickness of each plate and metal is removed to form the channels by a chemical or an electro-chemical process. The channels 18 have a width in the range 1.0mm to 5.0mm and a depth in the order of 0.2mm to 1.5mm. Depending upon the depth of the channels, the plate may have a thickness in the order of 1.0mm to 2.0mm and the end plates 12 may have a thickness in the order of 10.0mm.

The region of each plate which is not occupied by the channels 18, that is the marginal region 19 and the ridges between each of the channels, is used to provide metal-to-metal contact with adjacent plates in the diffusion bonding of the adjacent plates.

The plate 11 as shown in Figure 3 is constructed and formed in much the same manner as the plate 10, except that it has a unidirectional passage 20 which extends downwardly from an outlet region 21 in the top end 22 of the plate to an inlet region 23 in the bottom end 24 of the plate. The passage is constituted by a plurality of linear channels 25 (each of which is indicated by a single line in Figure 3) and the channels are separated by intervening ridges. Opposite side regions 26 of the plate are unchanneled and these regions, together with the channel-separating ridges, are bonded in face-to-face contact with adjacent plates during diffusion bonding to all of the plates of the heat exchanger.

All of the channels 25 in the plate 11 are open to the top and bottom of the heat exchanger as shown in Figure 1 and, thus, permit the flow of a first fluid in a vertical direction through alternative ones of the plates in the heat exchanger. Similarly, all of the channels 18 in the plates 10 open to the side edges of the heat exchanger in the inlet and outlet regions 14 and 16. The inlet and outlet regions 14 and 16 are covered by inlet and outlet headers 27 and 28 which permit a second fluid to be directed into and from the passage in the alternately stacked plates 10.

The heat exchanger as shown in Figure 1 may be

employed, for example, for chilling water. Water is directed into the upper header 27 by way of an inlet pipe 29 and out through the lower header 28 from which it is conveyed by a pipe 30. In passing from the inlet to the outlet headers, the water makes three transverse passes across the plates 10, reversing in direction during the second pass.

The complete heat exchanger is intended to be submerged in a refrigerant, so that the refrigerant when boiling is driven upwardly through the vertically extending passages in the plates 11 by buoyancy effects. As an alternative, headers could be mounted to the lower and upper ends of the heat exchanger for conveying refrigerant into and from the plates 11.

Figure 4 of the drawings shows a heat exchanger of a type which incorporates inlet and outlet headers for directing each of two fluids into and from the heat exchanger. Thus, the heat exchanger in this case includes one pair of inlet and outlet headers 31 and 32 for directing a first heat exchange fluid through one group of plates 10 (as shown in Figure 2), while a second pair of inlet and outlet headers 33 and 34 is employed for directing a second fluid through a second group of alternately located (interleaved) plates 35 or 36.

The plate 35 is shown in detail in Figure 5A and it can be seen to have a passage 37 which makes three vertically extending passes along a substantial part of the length of the plate. The passage 37 in this plate is formed in much the same way as that which has been described in the context of the plate shown in Figure 2 and it is constituted by a plurality of channels 38 extending between inlet and outlet regions 39 and 40 in the bottom and top of the plate.

The plate 36 in Figure 5B is similar to that which is shown in Figure 5A, except that it has a passage 41 which makes three horizontal passes across a substantial part of the plate and which is constituted by a plurality of channels 57. However, unlike the plate which is shown in Figure 2 which also makes horizontal passes, the plate which is shown in Figure 5B has a passage which connects with lower and upper inlet and outlet regions of the plate.

By using appropriately configured plate passages, coflow, counterflow and crossflow heat exchange may be achieved. Thus, by interleaving the plates of Figures 2 and 5B, counterflow thermal contact between fluid streams (e.g. two water streams) may be achieved. Again, by interleaving the plates of Figures 2 and 3 or Figures 2 and 5A, a combination of coflow, counterflow and crossflow heat exchange may be achieved. Thus, by providing one or both groups of plates in each stack with passages which make reverse direction passes, a considerable degree of flexibility can be built into the design of heat exchangers.

Figures 6 and 7 illustrate two further heat exchanger arrangements which, in each case, incorporate plates of the type shown in Figure 3 interlaced with plates 43 of the type shown in Figure 8.

The plate 43 as shown in Figure 8 is similar to that which is shown in Figure 2, except that it includes two separate fluid flow passages 44 and 45 which are each constituted by a plurality of channels 58. These

passages each make three passes across the width of the plate and they have separate inlet zones 46 and 47 in one edge 48 of the plate. However, both of the passages terminate or exit in a common outlet zone 49 in an opposite edge 50 of the plate.

The heat exchanger as shown in Figure 6 provides for the merging of two inlet streams into one outlet stream, this permitting the possible combination of crossflow, counterflow and coflow heat exchange within the exchanger. Two headers 51 and 52 are employed for directing separate streams of a first fluid into the inlet zones 46 and 47 in the plates 43 and a single outlet header 53 is employed to cover the outlet zone 49 in the plates 43. The second fluid is directed upwardly through the heat exchanger from header 33 to header 34.

By using the plate 43 in the heat exchanger configuration as shown in Figure 7, a total number of six passes may be achieved and, moreover, the inlet and outlet for the first fluid may be located on one side of the heat exchanger. This may have distinct advantages in certain applications.

Thus, as shown in Figure 7 an inlet header 54 is provided for directing a first heat exchange fluid into the heat exchanger and an outlet header 55 is provided on the same side of the heat exchanger for conveying the same fluid from the heat exchanger.

A further header 56 is located on the opposite edge of the heat exchanger and it functions simply to bridge all of the channels at the outlet zone 49 of the plates 43.

Variations and modifications may be made in respect of the various plate structures and heat exchange configurations which have been described above in the context of the various embodiments of the invention. For example, while the individual channels which go to form the various passages are shown in the drawings to have right-angle bends, the bends may be rounded to reduce pressure drop in the fluid when changing direction between successive passes in the plates. Again, while the various channels are shown in the drawings to be linear, they may be formed to follow a zig-zag path. Again, whilst the various channels have been shown to be separate for their entire length in each of the plates, some or all of the channels in each passage may be bridged by intersecting channels to permit pressure equalisation and/or to permit a reduction in the number of channels which actually extend to the inlet and/or outlet zones in the various plates.

The invention has been hereinbefore described and illustrated in terms of a heat exchanger which incorporates two types of plates or, more particularly, which incorporates plates which have two separate fluid flow passages through which two heat exchange fluids are directed for thermal contact. However, it will be understood that the heat exchanger may be constructed to incorporate further fluid flow passages for conveying further fluids which may be required to participate in an exchange of heat. Thus, the following claims should not be construed as excluding heat exchanger constructions which have three or more separate heat exchange passages for accommodating three

or more heat exchange fluids.

Claims

1. A heat exchanger comprising a plurality of flat metal plates (10 and 11, or 10 and 35 or 36, or 43 and 11 or 35 or 36) bonded together as laminations in face-to-face contact without any intervening gaskets, a first group of the plates (10 or 43) having a first fluid flow passage (13 or 44) formed in one face of each plate thereof and a second group of the plates (11 or 35 or 36) having a second fluid flow passage (20 or 37 or 41) formed in one face of each plate thereof, and means (27 and 26 or 31 and 32 or 51, 52 and 53 or 54, 55 and 56) associated with the first group of plates for directing a first fluid into and from the fluid flow passages in that group of plates and for keeping the first fluid separate from a second fluid which is in use directed through the fluid flow passages in the second group of plates; characterised in that the first and second fluid flow passages (13 or 44 and 20, 37 or 41) in the respective plates each comprise a plurality of channels (18, 58, 25, 38 or 57) which are formed within the thickness of the respective plates, the channels (18 or 58) in at least the first group of plates (10 or 43) make an odd number of passes across the width or along the length of the plates and the channels (18 or 58) within each fluid flow passage have approximately the same length.

2. The heat exchanger as claimed in claim 1 further characterised in that the channels (25) in the second group of plates (11) extend in a linear direction between opposite edges (22 and 24) of the plates.

3. The heat exchanger as claimed in claim 2 further characterised in that means (33 and 34) are associated with the second group of plates (11) for directing the second fluid into and from the fluid flow passages (20) in the second group of plates.

4. The heat exchanger as claimed in claim 1 further characterised in that the channels (38 or 57) in the second group of plates (35 or 36) make an odd number of passes across the width or along the length of the plates, such channels all having approximately the same length, and in that means (33 and 34) are associated with the second group of plates (35 or 36) for directing the second fluid into and from the fluid flow passages (37 or 41) in the second group of plates.

5. The heat exchanger as claimed in claim 3 or claim 4 further characterised in that the fluid flow passages (13, 20, 37, 41 or 44 and 45) in the respective plates extend from one marginal edge (14, 21, 39 or 46 and 47) to another marginal edge (16, 23, 40 or 49) of the plates.

6. The heat exchanger as claimed in any one of the preceding claims further characterised in

that individual ones of the plates (10 or 43) within the first group are interleaved with plates (11, 35 or 36) of the second group.

7. The heat exchanger as claimed in any one of the preceding claims further characterised in that the second fluid flow passage (20, 37 or 41) is formed also within the second face of each plate (10 or 43) of the first group of plates, and in that the first fluid flow passage (13 or 44) is formed also within the second face of each plate (11, 35 or 36) of the second group of plates.

8. The heat exchanger as claimed in claim 7 further characterised in that blank spacer plates, are located between and are bonded to adjacent ones of the plates.

9. The heat exchanger as claimed in claim 5 further characterised in that the means (27 and 28, 31 and 32, and 33 and 34) associated with the first and second groups of plates for directing fluids into and from the fluid flow passages within such groups of plates comprise headers which are secured to the marginal edges of the plates and bridge the plurality of bonded plates.

10. The heat exchanger as claimed in any one of the preceding claims further characterised in that the fluid flow passage (13 or 44 and 45) which is formed in each plate of the first group extends predominantly in a transverse direction and in that the fluid flow passage (11 or 37) which is formed in each plate of the second group extends predominantly in a longitudinal direction.

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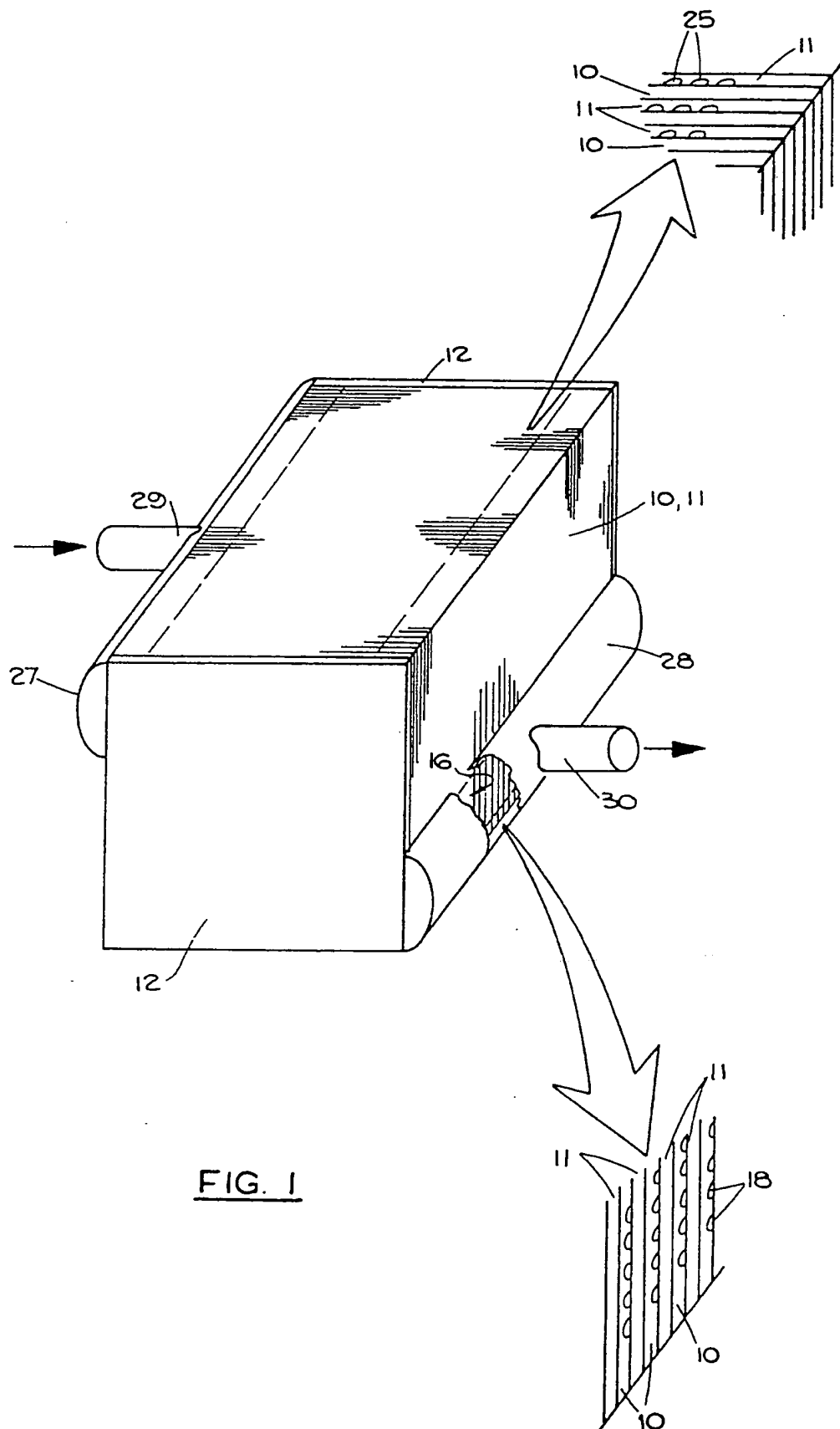


FIG. 1

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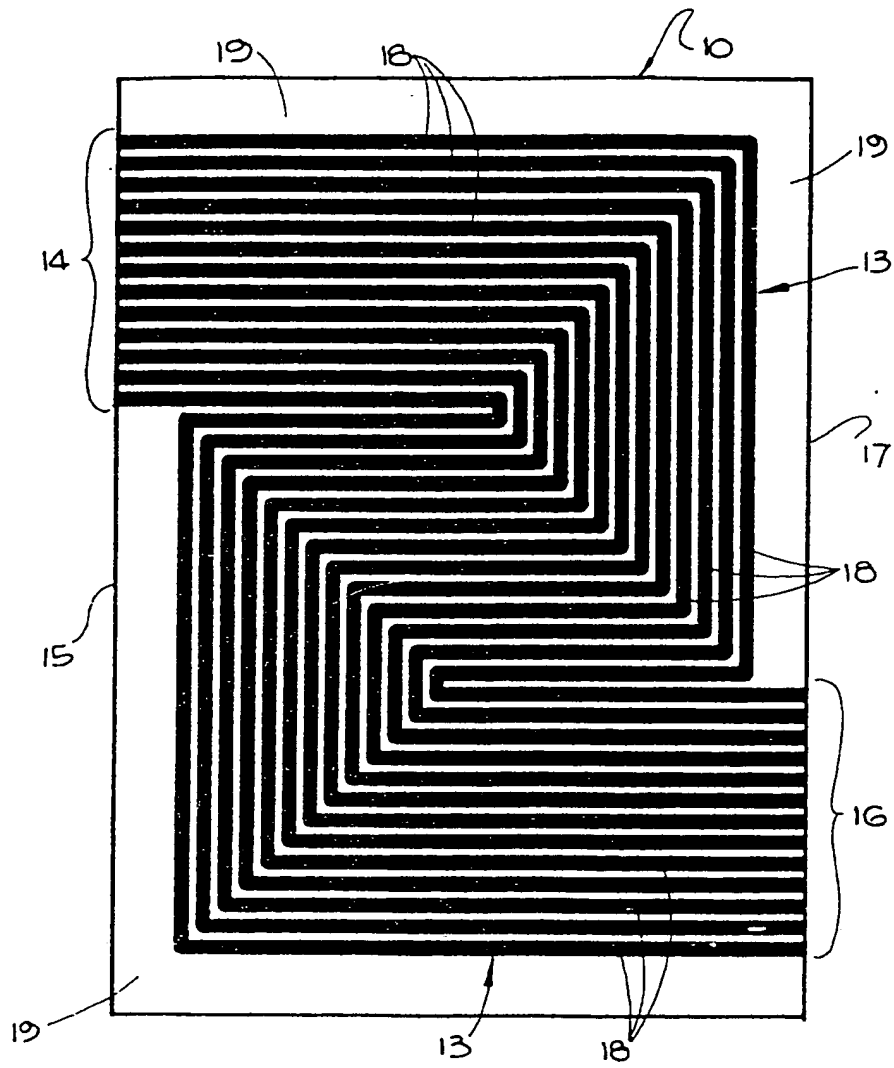


FIG. 2

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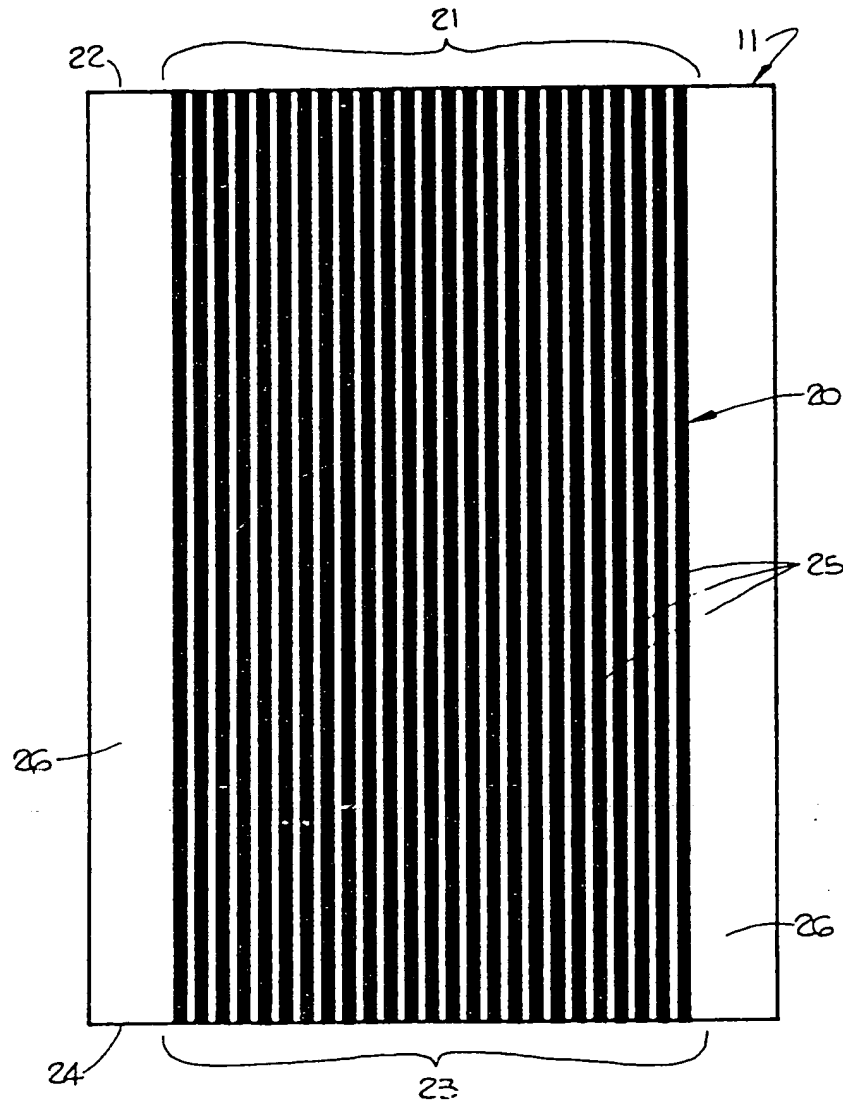


FIG. 3

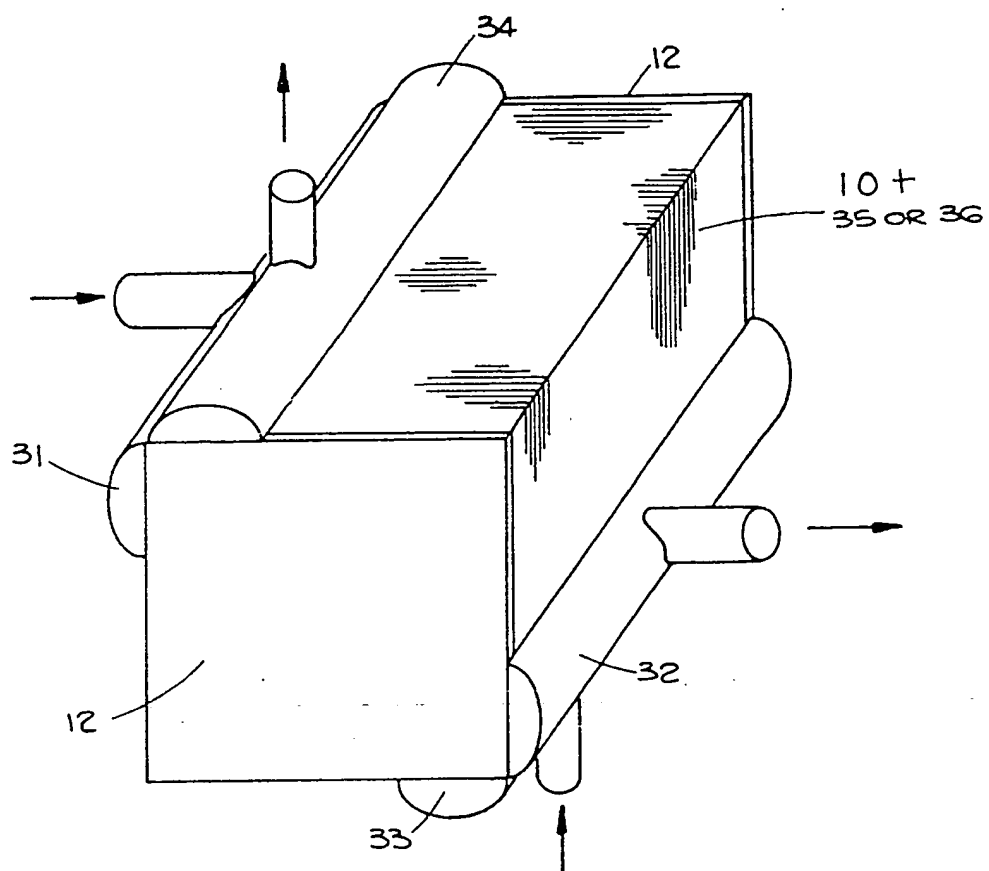


FIG. 4

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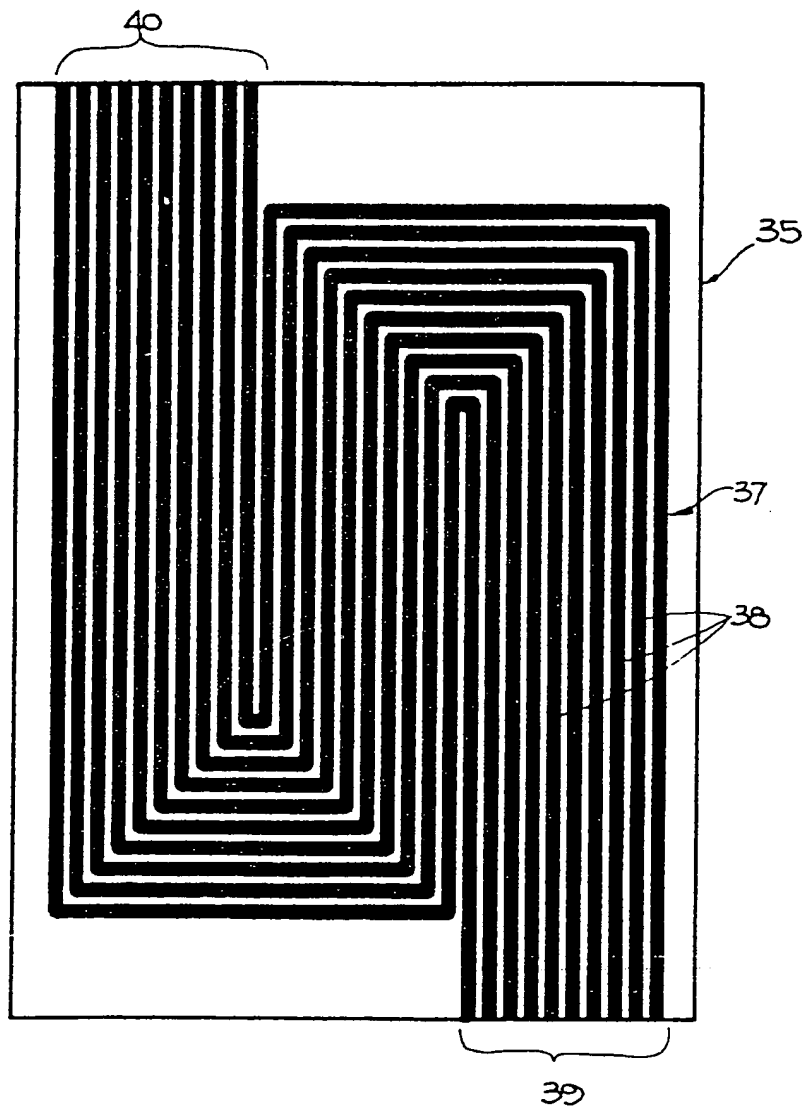


FIG. 5A

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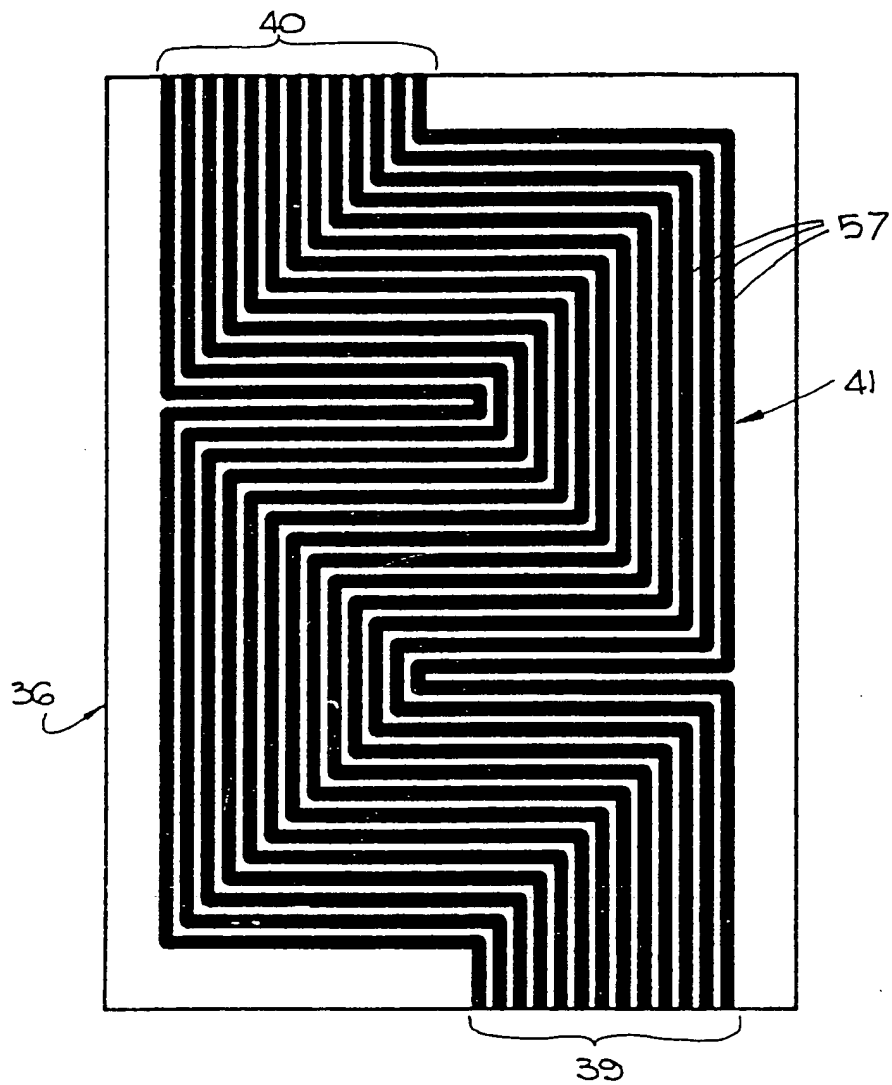


FIG 5B.

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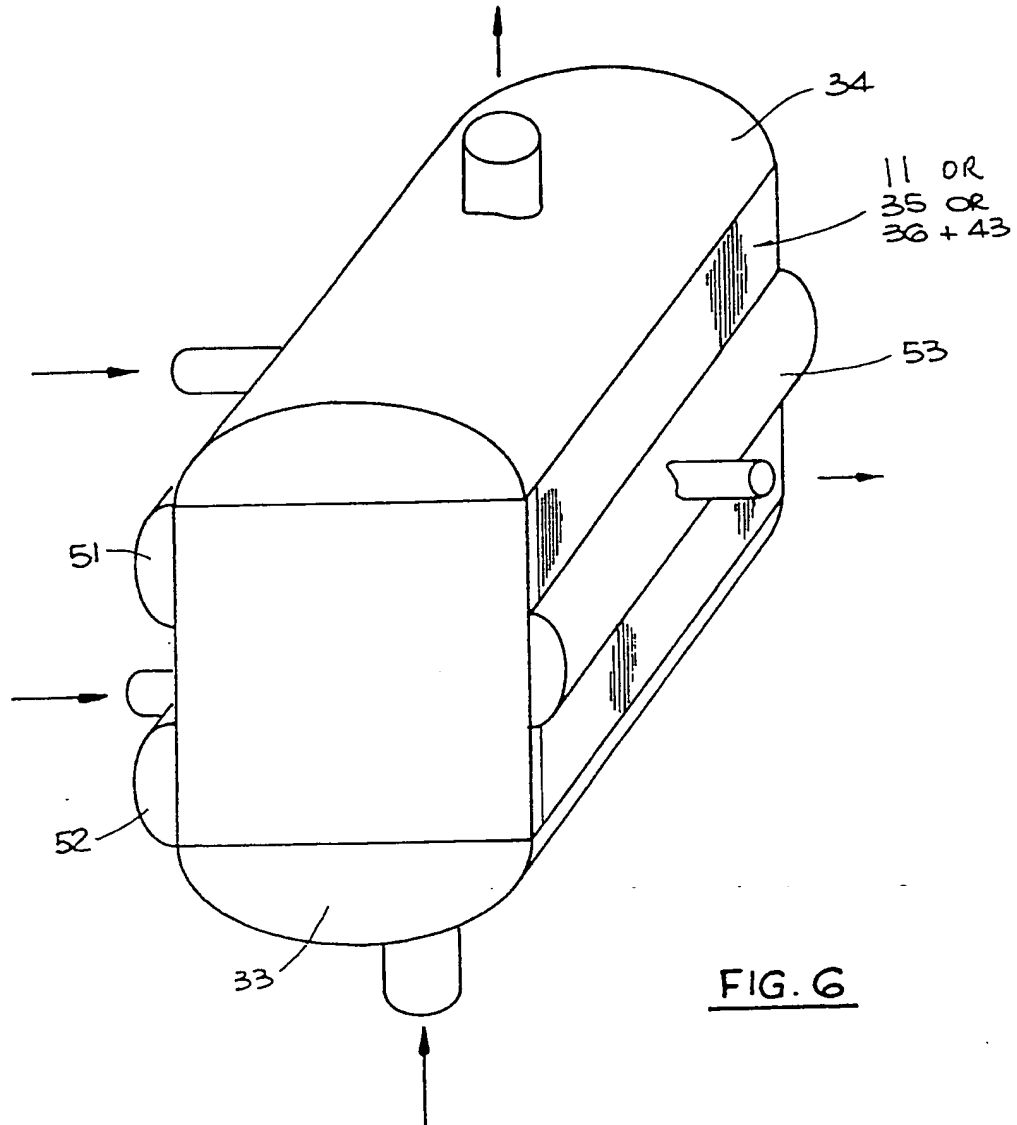


FIG. 6

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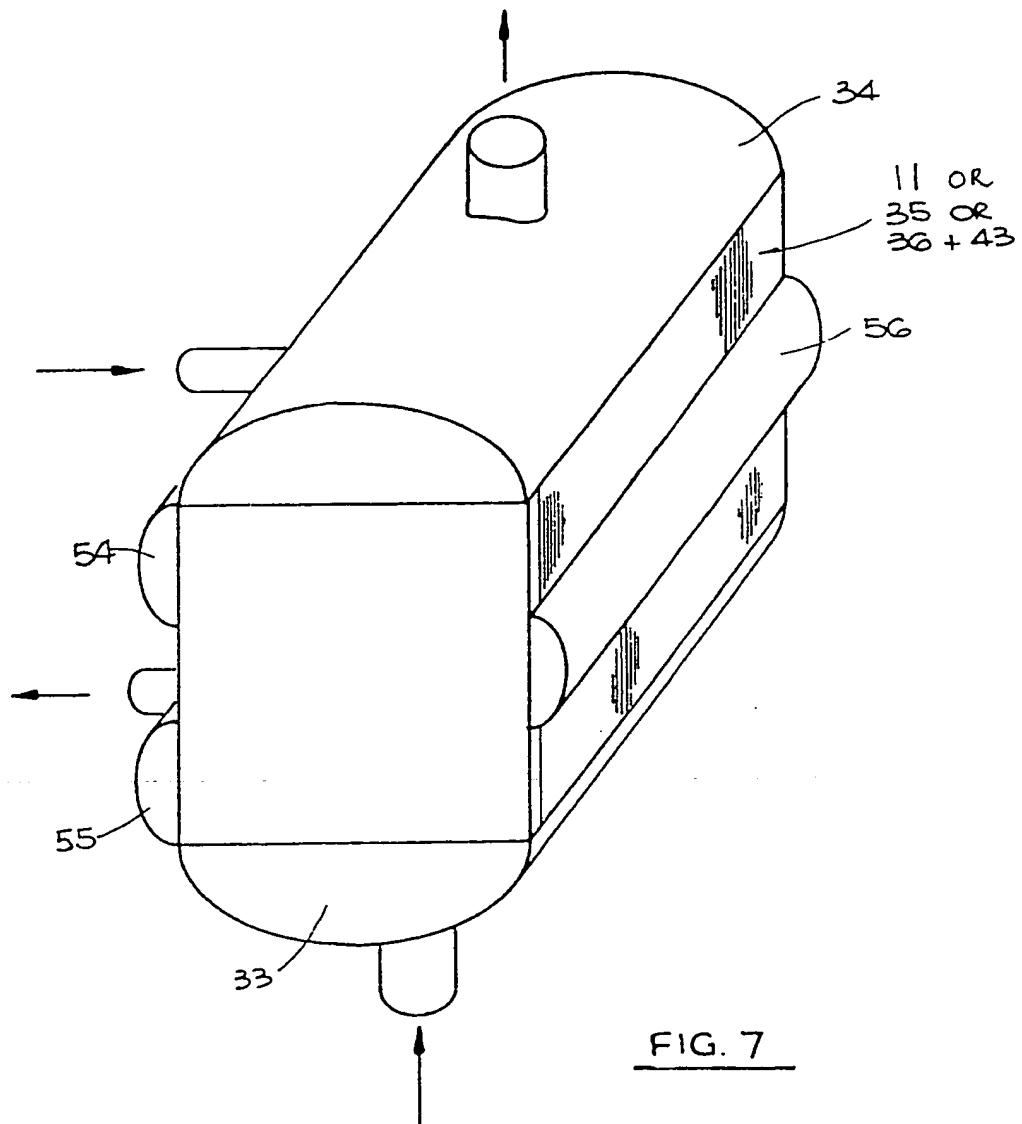
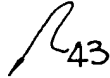


FIG. 7



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European Patent
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EUROPEAN SEARCH REPORT

Application Number

EP 88 30 4471

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
Y	EP-A-0 212 878 (HEATRIC PTY) * Abstract; figures 1-3,5,6,9A,10,11 * ---	1-6,9, 10	F 28 D 9/02 F 28 D 1/03 F 28 F 3/08
Y	GB-A- 429 412 (DE BOER) * Page 1, lines 103-106; page 2, lines 1-15; figure 5 * ---	1-6,9, 10	
A	US-A-1 662 870 (S. CLIFFE) * Page 2, lines 107-124; figures 1-7 * ---	7,8	
A	US-A-4 179 781 (LONG) ---		
A	US-A-3 490 522 (BIZZARRO) ---		
A	GB-A-1 150 403 (THE TRANE CO.) ---		
A	US-A-3 590 914 (DUNCAN) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
			F 28 D F 28 F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 22-08-1988	Examiner HOERNELL, L.H.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	